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Investigating the Reliability of Functional Parameters of Lube Oil Characteristics Integrity in Gen – Set Operation

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ABSTRACT

Evaluation of the performance of lube oil in the generator on the effect of load utilization was studied using reliability analysis. The continuous running of the generator set and the load utilization reduces the quality of the lube oil which influences the operational performance. The research work reveals constant failure of generator set when the quality of the lube oil is low and when allowed to run for a period of 400 hours. Data was generated in this study by the mechanism of increasing load utilization and monitoring the available load carried by the generator set at the initial hours less than 50 hours. The failure rate, corrective time failure, failure per year, gross margin, scraps disposal cost per incident and breakdown maintenance cost was evaluated. The result obtained demonstrates the best operational conditions to run a generator set for optimum performance and the range for the optimum performance was within $0 < 50 < 200$ hours output running hours before changing the lube oil in the generator set. The results obtained on evaluating the performance of lube oil in the generator using reliability analysis reveals that constant failure was observed as the characteristics of the lube oil decreases and the available load utilization reduces as well. Finally, this research work is found useful in monitoring, predicting and simulating the effect of load utilization and output running hours on the quality of the lube oil used in servicing generator set (loss in quality value due to load utilization and output running hours.

Key words: Investigating, reliability, functional parameters, lube oil, characteristics, integrity

1. INTRODUCTION

Approach of reliability analysis was used to evaluate the physiochemical properties of the lubricating oil in generator set with load utilization output over an incremental time of 50hrs to 400hrs. However, the characteristics of the lubricating oil was monitored with period of utilization as well as the available load the generator set can carried as the oil lost their values. The effective performance of the generator set to deliver higher power output for optimum utilization was investigated as well as the evaluation for reliability

in terms of the effect of lubricating oil characteristics. The physicochemical properties of the lubricating oil change as the running hours of the generator set increases from 50 hours to 400 hours.

The physicochemical parameters considered in this study includes density, pour point, flash point, kinematic viscosity, PH, refractive index, viscosity index, water content, colour, appearance, TBN (Mg K0H/9), sediment, sulphate Ash and TAN (mg K0H). The initial concentration of the fresh lubricating oil was examined as well as the operational period of 50hours to 400hours of an incremental step of 50hours. The physicochemical parameters of the lubricating oil were analyzed and the obtained values recorded with the available load powered.

The lubricating oil characteristics per running hours were related to failure experienced as well as the output performance, since it was observed that the quality of the lubricating oil decreased with increased in the running hours as well as decreased in available load utilization.

Identification of operational constraints were considered in this dissertation as well as the goal of this research is to evaluate the performance of the lubricating oil as resulted to failures of the generator set because of the effect of lost in value on the physicochemical properties of lube oil [1].

Investigation conducted by various research groups reveals that a voltage interruption influences the optional performance of generator set often caused by lost in value of the lubricating oil and this causes failures [2-4]. The researchers further concluded that these failures could causes an entire generator set to shut down or stop to function. In most cases, this sudden shut down influence the operational components of the generator set negatively, for instance failure of oil filter system due to loss of value of the lubricating oil may influence the optimum performance of other components, such as, radiator, pump etc [5-6]. The scenario may cause failure or unwanted stopping of the generator set. However, to ensure reliability in the operation of generator set, continuous maintenance is required for improvement [7]. Reliability in case is required for the improvement of the generator set to perform the duty as well as servicing will enhance the service life of the generator set [8-10]. Other researchers attributed the reliability of generator set in terms of operating conditions by obeying the rules and regulation of the manual by ensuring that the generator set is operated according to the guidelines [11-13].

Research conducted on generator set reveals that each generator set has a designed load capacity and any load applied to it either above or below the load capacity influence the performance of the generator set [14]. Therefore, the generator set requires constant servicing to enable maintain high reliability value as well as good shape as to meet up with the required load designed for it and this can be constantly achieved by the application of good and efficient lubricating oil of high quality as recommended by the manufacturer [15-18].

The proper interactions of the lubricating oil in the generator set engine components, aids in reducing friction and increase the output performance [19]. The frictional contact of lubricating oil and the engine components influence the characteristic and the chemical composition of the functional parameters of the lubricating oil. However, constant failure of the generator set reduces the reliability value of the generator set [20-21]. On the note that the lubricating oil has lost its value, the aim of lubricating value is then lost and, in most case, metal rubbing will increase and reduction in performance will be observed. This will reduce reliability of the generator set in discharging the available load for utilization.

2. MATERIALS AND METHOD

2.1. Materials

The materials used are 15liters of Mobil (MOBIL DELVAC™ 1340, SAE 40) lubricating 0il, 4-Air conditioners, 3-water heaters of, 3-refrigerators, 30bulbs and 3-pressing iron and a 20KVA Maikano generator set. The measuring instrument used are viscometer, hydrometer, flash point tester, pH meter and refractometer.

2.2. The Model Development and Formulation

In this research work, mathematical models were developed to ascertain the significance of lube oil performance in terms of degradation of the characteristics of the formational parameters on the load utilization. The model was developed by considering the following assumption such as establishing optimum study load interval of 400hrs (OSLI) and allowable load failure (ALF) and corrective time per failure. In this study 20KVA generator sets were considered as well as the available load utilization. The following equations were formulated based on the adopted research conducted by various research groups [16-17].

2.2.1. Mean Time between Failures (MTBF)

The mean time between failures can be defined in terms of the ratio of Optimum Study Load Interval (OSLI) to allowable load failure (ALF) therefore; the mathematical expression is given as

$$MTBF = \frac{OSLI}{ALF} \tag{1}$$

Let OSLI = Y, ALF = x and MTBF = λ

Therefore, the mean time between failures can be written as

$$MTBF = {}^{y}\!/_{x} = \lambda \tag{2}$$

2.2.2. Total Mean Time between Failure

The total mean time between failures can be expressed in terms of total allowable loads each generator can carry without failure as well as establish the total failures per allowable load for the various generators of various capacitors. Therefore,
Total failures per allowable =

$$\left(\frac{1}{\lambda}\right)_{50rpm} + \left(\frac{1}{\lambda}\right)_{100rpm} + \left(\frac{1}{\lambda}\right)_{150rpm} + \left(\frac{1}{\lambda}\right)_{200rpm} + \left(\frac{1}{\lambda}\right)_{250rpm} + \left(\frac{1}{\lambda}\right)_{300rpm} + \left(\frac{1}{\lambda}\right)_{350rpm} + \left(\frac{1}{\lambda}\right)_{400rpm} \tag{3}$$

However, the total mean time between failure (TMTBF) can be denoted as λ^1 as well as expressed as

$$\lambda^1 = TMTBF = \frac{Annual\ hour\ per\ year}{Total\ failure\ per\ year} \tag{4}$$

In this case, the mean time between failure λ^1or TMTBF can be expressed mathematically as:

$$\lambda^1 = TMTBF = \frac{Annual\ revolution\ per\min ute\ per\ year}{Total\,load\ failure\,per\ year} \tag{5}$$

Where annual Times (Hours) per year is (AHRSPY), total load failures per year (TLFPY)

Therefore equation (5) can be written as

$$\lambda^1 = TMTBF = \frac{ARPMPY}{TLFPY} \tag{6}$$

If AHRSPY is denoted by A^1 and TLFPY is also denoted by T^1, therefore equation (6) becomes $\lambda^1 = \frac{A^1}{T^1}$ (7)

2.2.3. Failure Rate (FR)

The failure rate upon the influence of load was formulated using the normal concept of failure rate expression, thus:
Failure rate = ALT/OSLI (8)

$$\text{Failure rate} = \frac{Allowableload\ failure}{Optimumstudyload\,\text{int}\,erval} \tag{9}$$

$$FR = \frac{1}{MTBF} = \frac{1}{OSLI/ALT} = \frac{1}{\lambda} = \frac{1}{y/x} \; or \; x/y \tag{10}$$

The mathematical expression for the various generator capacity considered in this study, their failure rate can be expressed as:

$$FR_{11KVArpm} = \left(\frac{1}{MTBF}\right)_{11KVA-rpm} = \left(\frac{1}{OSLI/ALT}\right)_{11KVA-rpm} = \left(\frac{1}{\lambda}\right)_{11KVA-rpm} = \left(\frac{1}{y/x}\right)_{11KVA-rpm} or\,(x/y)_{11KVA-rpm} \tag{11}$$

$$FR_{20KVArpm} = \left(\frac{1}{MTBF}\right)_{20KVA-rpm} = \left(\frac{1}{OSLI/ALT}\right)_{20KVA-rpm} = \left(\frac{1}{\lambda}\right)_{20KVA-rpm} = \left(\frac{1}{y/x}\right)_{20KVA-rpm} or\,(x/y)_{20KVA-rpm} \tag{12}$$

$$FR_{40KVArpm} = \left(\frac{1}{MTBF}\right)_{40KVA-rpm} = \left(\frac{1}{OSLI/ALT}\right)_{40KVA-rpm} = \left(\frac{1}{\lambda}\right)_{40KVA-rpm} = \left(\frac{1}{y/x}\right)_{40KVA-rpm} or\,(x/y)_{40KVA-rpm} \tag{13}$$

2.2.4. Total Failure Rate

The total failure rate upon influence of load utilization for various generator capacity can be expressed mathematically as stated below:

For 11 KVA Generator

$$(TFR)_{11KVA} = \begin{bmatrix} \left({}^{50}FR\right)_{11KVA} + \left({}^{100}FR\right)_{11KVA} + \left({}^{150}FR\right)_{11KVA} + \left({}^{200}FA\right)_{11KVA} + \left({}^{250}FA\right)_{11KVA} + \left({}^{300}FA\right)_{11KVA} \\ + \left({}^{350}FA\right)_{11KVA} + \left({}^{400}FA\right)_{11KVA} \end{bmatrix} \tag{14}$$

For 20 KVA generator

$$(TFR)_{11KVA} = \begin{bmatrix} \left({}^{50}FA\right)_{20KVA} + \left({}^{100}FA\right)_{20KVA} + \left({}^{150}FA\right)_{20KVA} + \left({}^{200}FA\right)_{20KVA} + \left({}^{250}FA\right)_{20KVA} + \left({}^{300}FA\right)_{20KVA} \\ + \left({}^{350}FA\right)_{20KVA} + \left({}^{400}FA\right)_{20KVA} \end{bmatrix} \tag{15}$$

For 40kva Generator

$$(TFR)_{11KVA} = \begin{bmatrix} \left({}^{50}FA\right)_{40KVA} + \left({}^{100}FA\right)_{40KVA} + \left({}^{150}FA\right)_{40KVA} + \left({}^{200}FA\right)_{40KVA} + \left({}^{250}FA\right)_{40KVA} + \left({}^{300}FA\right)_{40KVA} \\ + \left({}^{350}FA\right)_{40KVA} + \left({}^{400}FA\right)_{40KVA} \end{bmatrix} \tag{16}$$

2.2.5. Development of Functional Parameters

2.2.5.1. Failures per Year (FPY)

The failures per year (FPY) upon the influence of load on various generator capacities can be expressed mathematically as:

$$FPY = \frac{[\,failure rate of\ each\ product upon the inlfuence of\ load]}{[annual hours\ per\ year]} \times \tag{17}$$

$$FPY = \left(\frac{ALF}{OSLI}\right)(AHPY) \tag{18}$$

2.2.5.2. Total Failure per Year (TFPY)

The total failure per year can be formulated by considering the definition and the mathematical expression of the failure per year, therefore, we can express the total failure per year as the summation of failure per year (FPY) for each generator product examined thus:

$$TFPY = \sum \begin{bmatrix} {}^{50}(FPY)_{rpm} + {}^{100}(FPY)_{rpm} + {}^{150}(FPY)_{rpm} + {}^{200}(FPY)_{rpm} + {}^{250}(FPY)_{rpm} + {}^{300}(FPY)_{rpm} \\ + {}^{350}(FPY)_{rpm} + {}^{400}(FPY)_{rpm} \end{bmatrix} \tag{18}$$

Therefore, for 11KVA we have

$${}^{11KVA}(TFPY) = \sum \begin{bmatrix} {}^{50}(FPY)_{rpm} + {}^{100}(FPY)_{rpm} + {}^{150}(FPY)_{rpm} + {}^{200}(FPY)_{rpm} + {}^{250}(FPY)_{rpm} + {}^{300}(FPY)_{rpm} \\ + {}^{350}(FPY)_{rpm} + {}^{400}(FPY)_{rpm} \end{bmatrix} \tag{19}$$

For 20KVA generator we have

$${}^{20KVA}(TFPY) = \sum \begin{bmatrix} {}^{50}(FPY)_{rpm} + {}^{100}(FPY)_{rpm} + {}^{150}(FPY)_{rpm} + {}^{200}(FPY)_{rpm} + {}^{250}(FPY)_{rpm} + {}^{300}(FPY)_{rpm} \\ + {}^{350}(FPY)_{rpm} + {}^{400}(FPY)_{rpm} \end{bmatrix} \tag{20}$$

For 40KVA generator we have

$${}^{40KVA}(TFPY) = \sum \begin{bmatrix} {}^{50}(FPY)_{rpm} + {}^{100}(FPY)_{rpm} + {}^{150}(FPY)_{rpm} + {}^{200}(FPY)_{rpm} + {}^{250}(FPY)_{rpm} + {}^{300}(FPY)_{rpm} \\ + {}^{350}(FPY)_{rpm} + {}^{400}(FPY)_{rpm} \end{bmatrix} \tag{21}$$

2.2.5.3. Total Corrective Time per Failure (TCTPF)

The total corrective time per failure (TCTPF) was formulated using the mathematical express stated below:

$$(TCTPF) = \begin{bmatrix} Corrective time\ per\ failure of\ each\ product upon the \inf leunce of\ load \\ \times\ failure per\ year of\ each\ product upon\ the \inf leunce of\ load / \\ total\ failure per\ year upon the \inf leunce of\ load \end{bmatrix} \quad (22)$$

Therefore

$$TCTPF = \frac{\begin{matrix} {}^{50}(CTPF)_{rpm}\ {}^{50}(TPY)_{rpm} + {}^{1000}(CTPF)_{rpm}\ {}^{1000}(TPY)_{rpm} + {}^{150}(CTPF)_{rpm}\ {}^{150}(TPY)_{rpm} \\ + {}^{200}(CTPF)_{rpm}\ {}^{250}(TPY)_{rpm} + {}^{300}(CTPF)_{rpm}\ {}^{350}(TPY)_{rpm} + {}^{400}(CTPF)_{rpm}\ {}^{450}(TPY)_{rpm} \end{matrix}}{TFPY} \quad (23)$$

2.2.5.4. Lost Time per Year (LTPY)

The lost time per year was formulated as described below:

$$\begin{aligned} LTPY &= [Failures of\ each\ production per\ year upon \inf leunce of\ load] \times \\ &[Corrective time\ for each\ producti] \end{aligned} \quad (24)$$

2.2.5.5. Total Lost Time per Year (TLTPY)

The total lost time per year for each of the system can be evaluated using the mathematical expression stated below:

$$\begin{aligned} {}^{11KVA}(TLTPY) = {}&{}^{50}(LTPY)_{rpm} + {}^{100}(LTPY)_{rpm} + {}^{150}(LTPY)_{rpm} + {}^{200}(LTPY)_{rpm} + {}^{250}(LTPY)_{rpm} + {}^{300}(LTPY)_{rpm} \\ &{}^{350}(LTPY)_{rpm} + {}^{400}(LTPY)_{rpm} \end{aligned} \quad (25)$$

2.2.6. Time Lost from Unreliability

It is necessary to determine the input cause because of shut down operation expressed in the generator upon the influence of lube oil characteristics in terms of efficiency to discharge the required output to power the necessary utilities of the operation area studied. In some cases the sudden shut down influence the generator performance as well as cause damage on the system which request finance for maintenance. The above mentioned points result to unreliability of the process system, therefore, there is a need to determine the cost of unreliability upon the influence of load, which influence the lube oil characteristics or functional parameters that controls and improves the output performance in load delivery. The determination of the cost of unreliability we lead us to the evaluation of gross margin, total gross margin, scrap disposal, total scrap disposal, break down maintenance, total breakdown maintenance, total lost cost of each generator and total lost cost of generator studied.

2.2.6.1. Gross Margin (GM)

The gross margin (GM) can be determined using the mathematical expression as stated below:

Gross margin (GM) = (lost time per year) x (lost gross margin $ x per hour) (26)

2.2.6.2. Total Gross Margin (TGM)

The total gross margin (TGM) can be determined by using the mathematical expression that examines the relationship between the lost time per year and lost gross margin in dollar x per hour. Therefore, the mathematical expression is given as:

$$TGM = {}^{50}[(RTPY)(LGM\ at\$\ per\ hour)]_{rpm} + {}^{100}[(RTPY)(LGM\ at\$\ per\ hour)]_{rpm} + {}^{150}[(RTPY)(LGM\ at\$\ per\ hour)]_{rpm} + {}^{200}[(RTPY)(LGM\ at\$\ per\ hour)]_{rpm} + {}^{250}[(RTPY)(LGM\ at\$\ per\ hour)]_{rpm} + {}^{300}[(RTPY)(LGM\ at\$\ per\ hour)]_{rpm} + {}^{350}[(RTPY)(LGM\ at\$\ per\ hour)]_{rpm} + {}^{400}[(RTPY)(LGM\ at\$\ per\ hour)]_{rpm} \quad (27)$$

2.2.6.3. Scrap Disposal Cost per Incident (SDCPI)

The scrap disposal cost per incident (SDCPI) can be determined using the mathematical expression stated below, thus:

$$SDCPI = \begin{pmatrix} Failure\ per\ year\ for\ each\ product \\ upon\ the\ influence\ of\ load \end{pmatrix} \times \begin{pmatrix} Scrap\ disposal\ cost\ of\ \$D\ per \\ incident\ upon\ the\ influence\ of\ load \end{pmatrix} \quad (28)$$

The breakdown maintenance cost = $\dfrac{Gross\ margin \times scrap\ disposal\ cost}{Total\ breakdown\ maintenance}$ (29)

2.2.6.4. Total Breakdown Maintenance Cost (TBdMc)

The total breakdown maintenance cost (TBdMc) can be determined using the mathematical expression in terms of the various generators as well as time (in terms of load capacity utilization).

$$TMdMc = {}^{50}(BdMc) + {}^{100}(BdMc) + {}^{150}(BdMc) + {}^{200}(BdMc) + {}^{250}(BdMc) + {}^{300}(BdMc) + {}^{350}(BdMc) + {}^{400}(BdMc) \quad (.30)$$

2.2.6.5. Total Lost Cost (TLC)

The total lost cost upon the influence of load utilization cab be expressed mathematically as:

$${}^{50}(TLC) = {}^{50}(GMC) + {}^{50}(SDC)\ {}^{50}(BdMc) \quad (31)$$

$${}^{100}(TLC) = {}^{100}(GMC) + {}^{100}(SDC)\ {}^{100}(BdMc) \quad (32)$$

$${}^{150}(TLC) = {}^{150}(GMC) + {}^{150}(SDC)\ {}^{150}(BdMc) \quad (33)$$

$${}^{200}(TLC) = {}^{200}(GMC) + {}^{200}(SDC)\ {}^{200}(BdMc) \quad (34)$$

$${}^{250}(TLC) = {}^{250}(GMC) + {}^{250}(SDC)\ {}^{250}(BdMc) \quad (35)$$

$${}^{300}(TLC) = {}^{300}(GMC) + {}^{300}(SDC)\ {}^{300}(BdMc) \quad (36)$$

$${}^{350}(TLC) = {}^{350}(GMC) + {}^{350}(SDC)\ {}^{350}(BdMc) \quad (37)$$

$${}^{400}(TLC) = {}^{400}(GMC) + {}^{400}(SDC)\ {}^{400}(BdMc) \quad (38)$$

3. RESULTS AND DISCUSSION

The obtained data from the occurrence of the failures due loss of value of the lube oil as a result of constant utilization and high load input are presented as described in appendix of Table 1. Table 2 and 3 illustrates the evaluated results from the developed model for purpose of expressing the variation on the functional parameters.

3.1. Analysis on Failure Rate against Time

Analysis was carried out to ascertain the failure rate of a generator set against time upon load utilization by a household as shown in Figure 1.

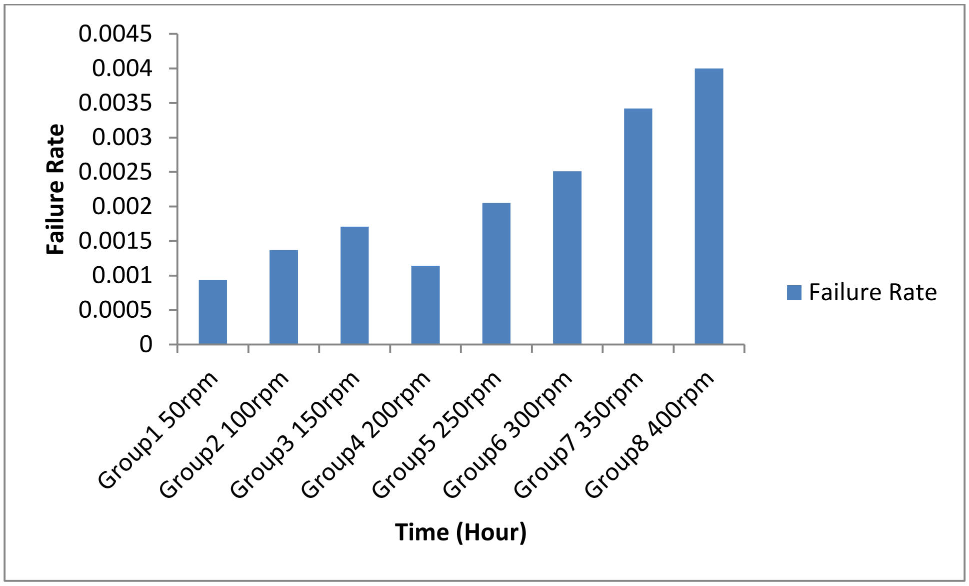

Figure 1: Graph of Failure Rate against Time (Hour)

Graph of failure rate against Times (Hours) of a generator set upon load utilization by a household is shown in Figure 1. The results obtained revealed the order of magnitude of the failure rate as group 8 (400hrs) > Group 7 (350hrs) > Group 6 (300hrs) > Group 5 (250hrs) > Group 3 (150hrs) > Group 2 (100hrs) > Group 4 (200hrs) > Group 1 (50hrs). The variation in the failure rate of the Gen set can be attributed to the variation on load utilization, available load inputted in the Gen set, the status or the characteristics of the lubricating oil in the engine system of the generator set as well as the physiochemical properties of the lubricating oil as determining factors for failure of the Gen set as a result of load application effect on the physicochemical properties of the lubricating oil influence the output pressure in relationship to available load utilization will also be affected and this causes failure in most cases as presented in Figure 4.9.

3.2. Analysis on Corrective Time failure against Time

The characteristics of the corrective time failure in terms of variation can be attributed to the available load inputted at the time of failure, load utilization, effect on physicochemical properties of the lubricating oil which influence the output pressure as well as the load required by the household power utilization as shown in Figure 2.

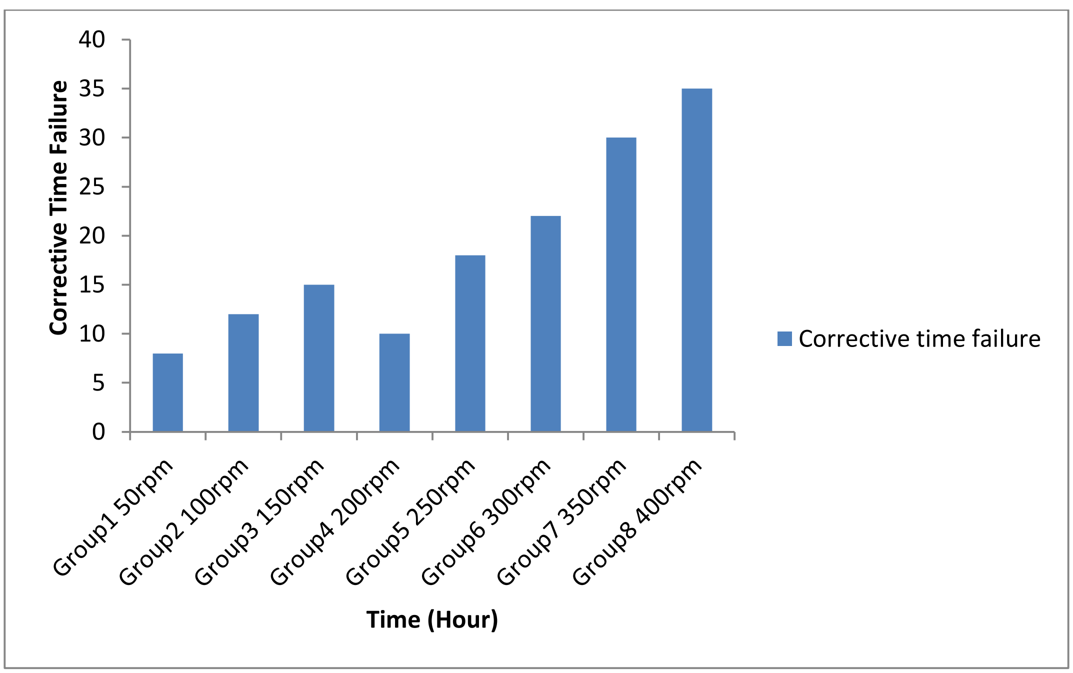

Figure 2: Graph of Corrective Time Failure against Time (Hour)

Figure 2 demonstrates the characteristics of the corrective time failure of the Gen set upon the influence on the lubricating oil characteristics. The order of magnitude in terms of corrective time failure of the Gen sets sampled as stated, 8 (400hrs) > Group 7 (350hrs) > Group 6 (300hrs) > Group 5 (250hrs) > Group 3 (150hrs) > Group 2 (100hrs) > Group 4 (200hrs) > Group 1 (50hrs).

3.3. Analysis of Lost Time per Year against Time

The lost time per year influence the cost of unreliability incurred in the maintenance of the Gen set as well as the effect on the household utilization of the available power due to constant failure of the Gen set leading to the high cost of maintenance and blackout period in the household. The variation in the characteristics of the lost time per year can be attributed to the variation in load utilization, effect on the physiochemical properties of the lubricating oil and other environmental factors.

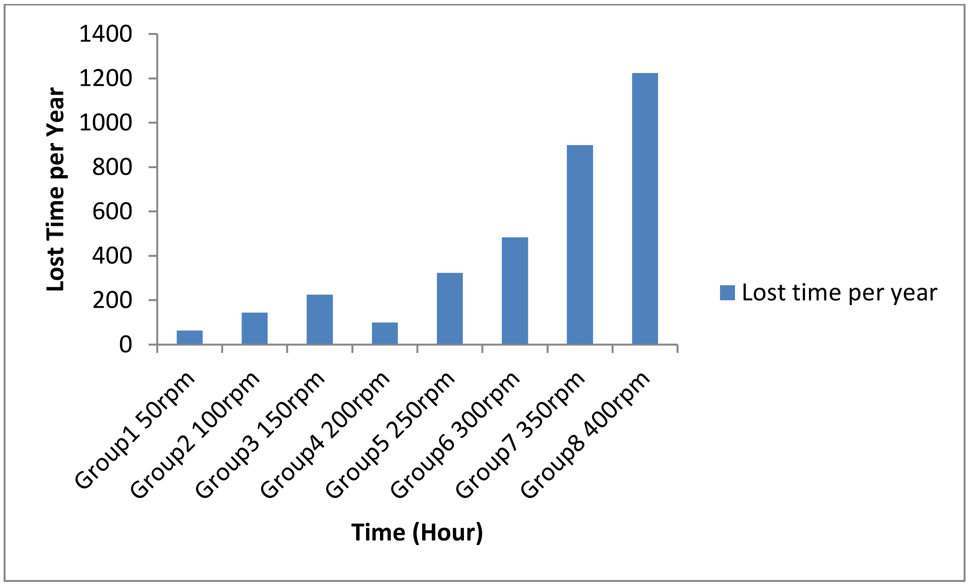

Figure 3: Graph of Lost Time per Year against Time (Hours)

Figure 3 shows the relationship between the lost times per year of the 20KVA generator set upon the influence of time. The results obtained shows that the order of magnitude in terms of lost time per year is Group 1 (50hrs) < Group 4 (200hrs) > Group 2 (100hrs) < Group 3 (150hrs) < Group 5 (250hrs) < Group 6 (300hrs) < Group 7 (350hrs) < Group 8 (400hrs).

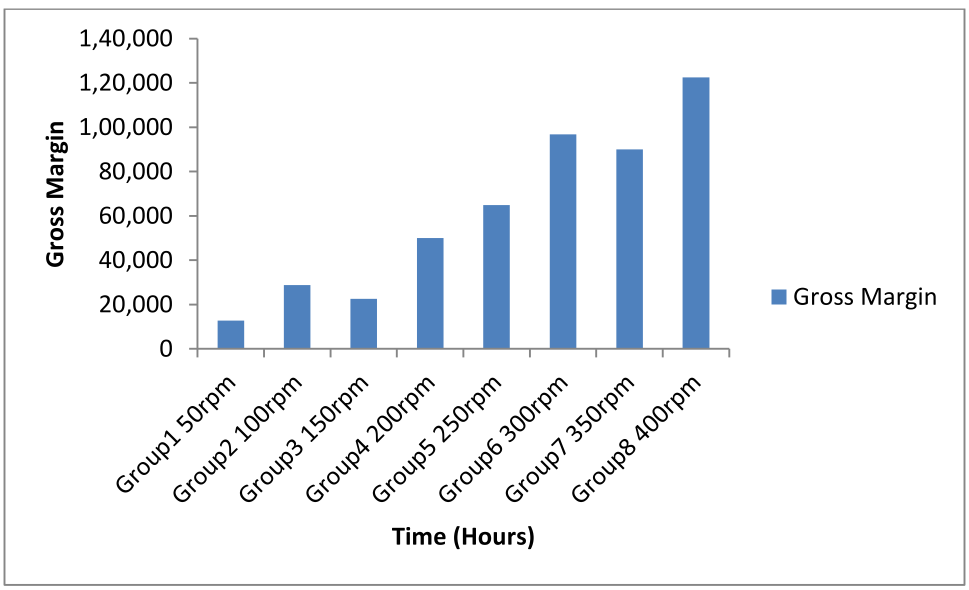

Figure 4: Graph of Gross Margin against Times (Hours)

3.4. Gross Margin against Time (Hours)

Increase in gross margin was experienced as the characteristics of the physicochemical properties of the lubricating oil wear out that is, losing its functional values as a result of overuse of the Gen set above, the recommended Standard by the International Organization. The variation in the characteristics of the gross margin number of Time (hours) load applied, load utilization and other factors.

Graph of Gross Margin against Time (hours) of 20KVA Gen sets was examined. The result obtained revealed that the order of magnitude of the gross margin profit of the operation in terms of reliability of the system is shown in Figure 4 as Group 1 (50hrs) < Group 3 (150hrs) <Group 2 (100hrs) < Group 4 (200hrs) < Group 5 (250hrs) < group 7 (350hrs) < Group 6 (300hrs) < group 8 (400hrs).

3.5. Scrap Disposal Cost per Incident against Time

The scrap disposal cost per incident increase with an increase in the unreliability of the generator sets system as shown in Figure 5.

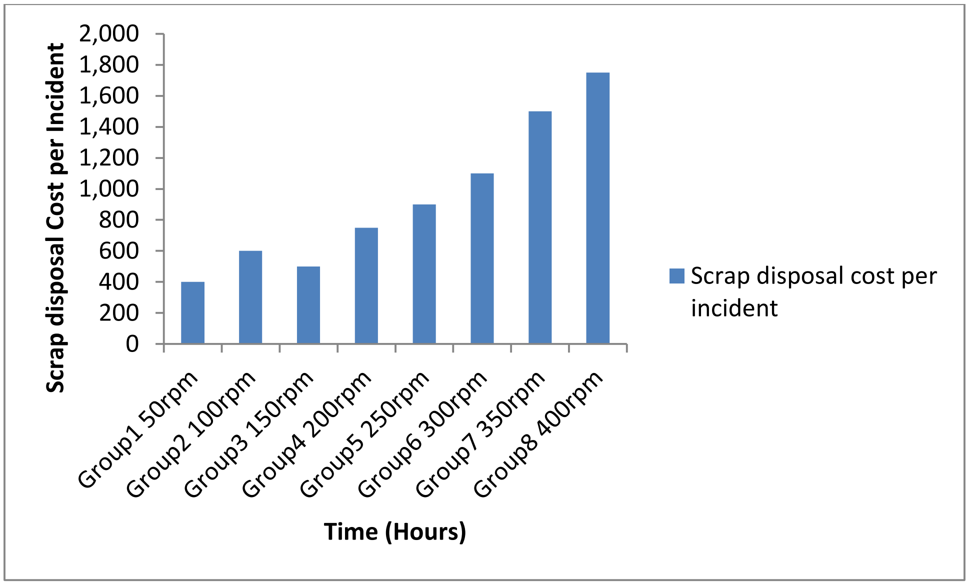

Figure 5: Graph of Scrap Disposal Cost per Incident against Time (Hours)

Figure 5 illustrates the characteristics of the scrap disposal cost per incident of the 20KVA generator set investigation on the influence of load applied, load utilization on the physicochemical properties of the lubricating oil in the engine system as well as their contribution toward the efficiency of output power or pressure generated.

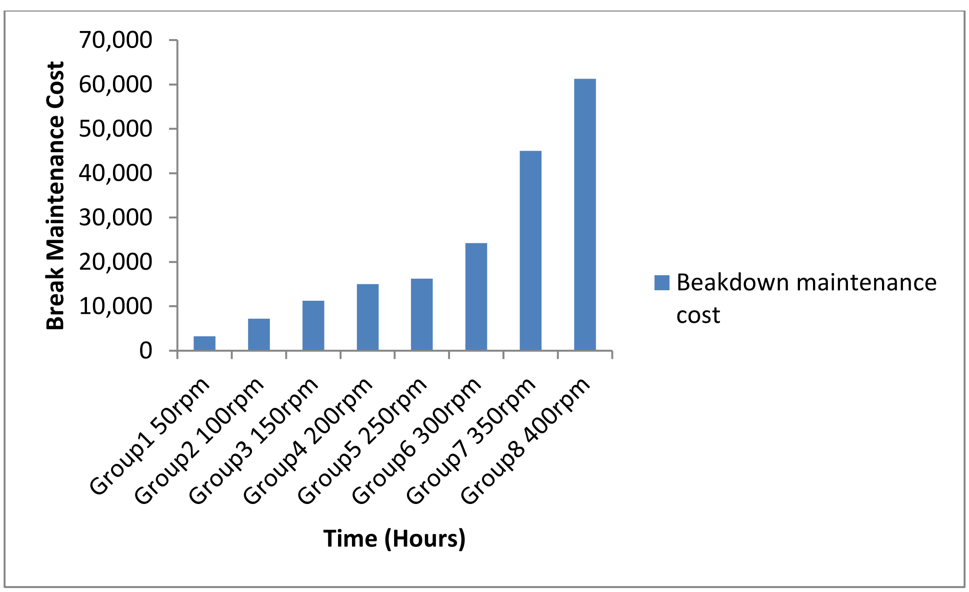

Figure 6: Graph of Breakdown Maintenance Cost against Time (Hours)

3.6. Breakdown Maintenance Cost against Time

The variation in the breakdown maintenance cost of the generator sets can be attributed to the variation in the number of times as well as the effect of the operation on the physicochemical properties of the lubricating oil.

Figure 6 show case the characteristics of the breakdown maintenance cost of 20KVA generator sets on the influence of load applied, load utilization on the characteristics of the lubricating oil. An increase in breakdown of the generator set was observed that the physicochemical properties of the lubricating oil wear out that is when its value is lost. The degree of unreliability will increase hereby causes an increase in maintainability and unsteady power supply to the household for utilization.

4. CONCLUSION

The research demonstrates the following significant points

i. The characteristics of the lube oil quality influence the performance the gen – set in terms of allowable load utilization.
ii. The degree of lube oil quality decreases as the time of utilization increases
iii. The functional parameters value varies as a result of variation in the characteristics of the lube oil in the gen – set due to continuous utilization
iv. Low quality of oil obtained resulted in continue failure as load input increased
v. The failure rate, corrective time failure, failure per year, gross margin, scraps disposal cost per incident, breakdown maintenance cost was determined in this investigation

APPENDIX

Table 1: Description of Data Collection of 20KVA Generator Sets in terms of Number of Times (Hours) Contributing to Failure on Load Utilization

Number of Times (Hours)	**Group 1 50hrs**	**Group 2 100hrs**	**Group 3 150hrs**	**Group 4 200hrs**	**Group 5 250hrs**	**Group 6 300hrs**	**Group 7 350hrs**	**Group 8 400hrs**
Failure	8	12	15	10	18	22	30	35

Table 2: Computational Values of Some of the Parameters for Various Number of Times (Hours)

Number of Times (Hours)	**Group 1 50hrs**	**Group 2 100hrs**	**Group 3 150hrs**	**Group 4 200hrs**	**Group 5 250hrs**	**Group 6 300hrs**	**Group 7 350hrs**	**Group 8 400hrs**
Failure rate	9.31×10^{-4}	1.37×10^{-3}	1.71×10^{-3}	1.14×10^{-3}	2.05×10^{-3}	2.51×10^{-3}	3.42×10^{-3}	4.0×10^{-3}
Corrective time failure	8	12	15	10	18	22	30	35
Lost time per year	64	144	225	100	324	484	900	1225

Table 3: Computational Values of Some Parameters for Various Number of Times

Number of Times (Hours)	Group 1 50hrs	Group 2 100hrs	Group 3 150hrs	Group 4 200hrs	Group 5 250hrs	Group 6 300hrs	Group 7 350hrs	Group 8 400hrs
Gross margin	12,800	28,800	22,500	50,000	64,800	96,800	90,000	122,500
Scrap disposal cost per incident	400	600	7,500	500	900	1,100	1,500	1750
Breakdown maintenance cost ($)	3,200	7,200	11,250	5000	16,200	24,200	45,000	61,250
Availability AV								

Funding

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Conflict of Interest

The author declares that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

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